Sources of atmospheric and deposited black carbon aerosols in Arctic spring

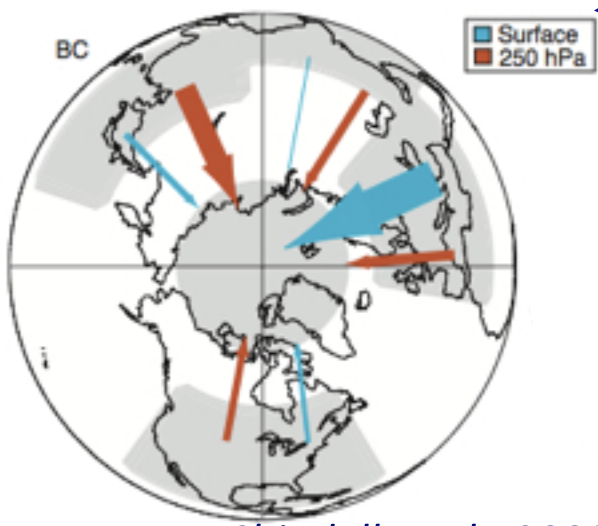
Qiaoqiao Wang, **Jenny A. Fisher**, Daniel J. Jacob
Harvard University

Jingqiu Mao, Eric M. Leibensperger, Claire C. Carouge, Philippe Le Sager,
Yutaka Kondo, Jose L. Jimenez, Michael, J. Cubison

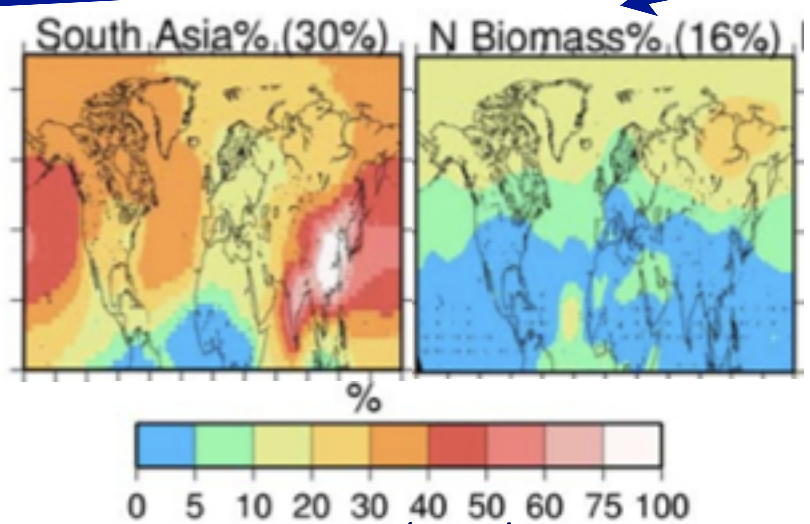
International Meeting on Open Burning and the Arctic: Causes, Impacts, and Mitigation Approaches
November 8-9, 2010

Motivation

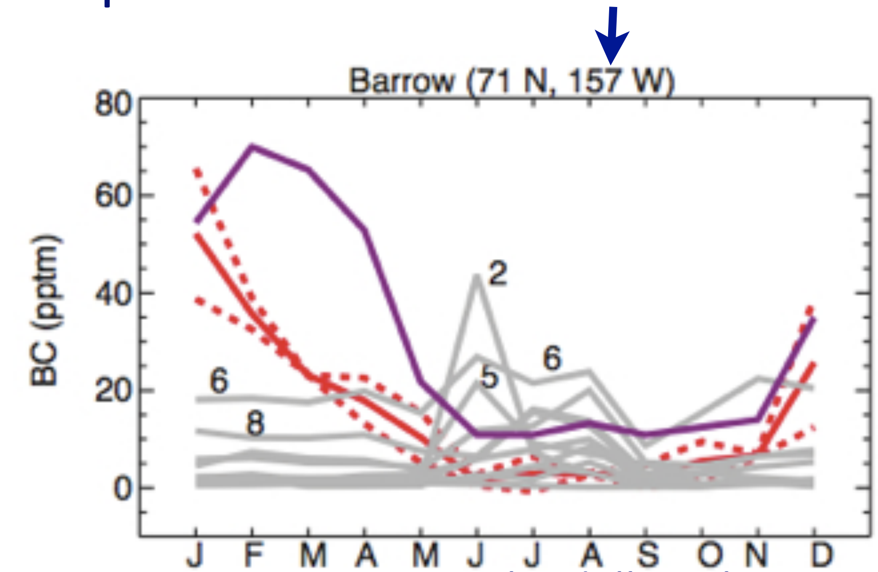
- Arctic **climate** is sensitive to **black carbon** (BC) both in the atmosphere and after deposition to snow
- **Models disagree** about the dominant **sources** of Arctic BC in the atmosphere and at the surface



Shindell et al., 2008

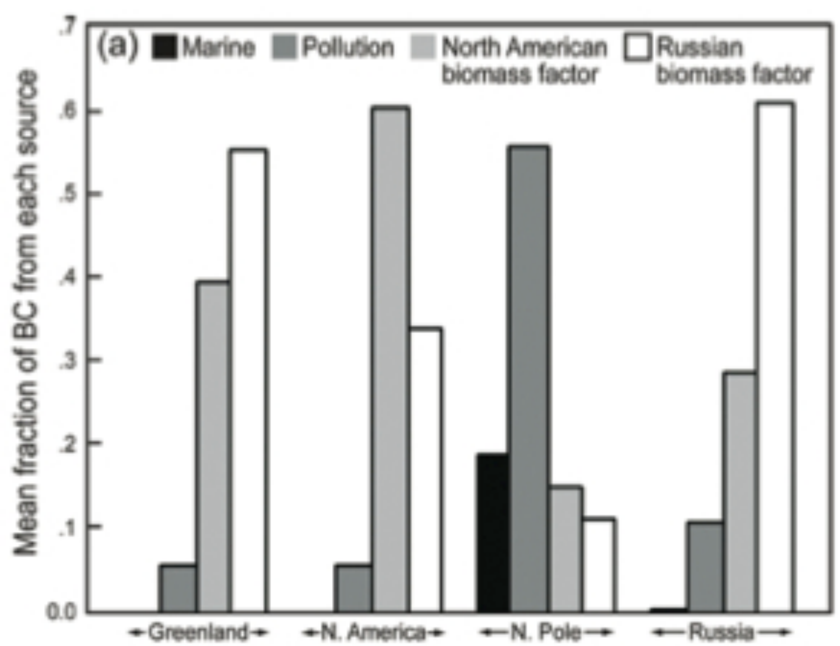


Koch and Hansen, 2005

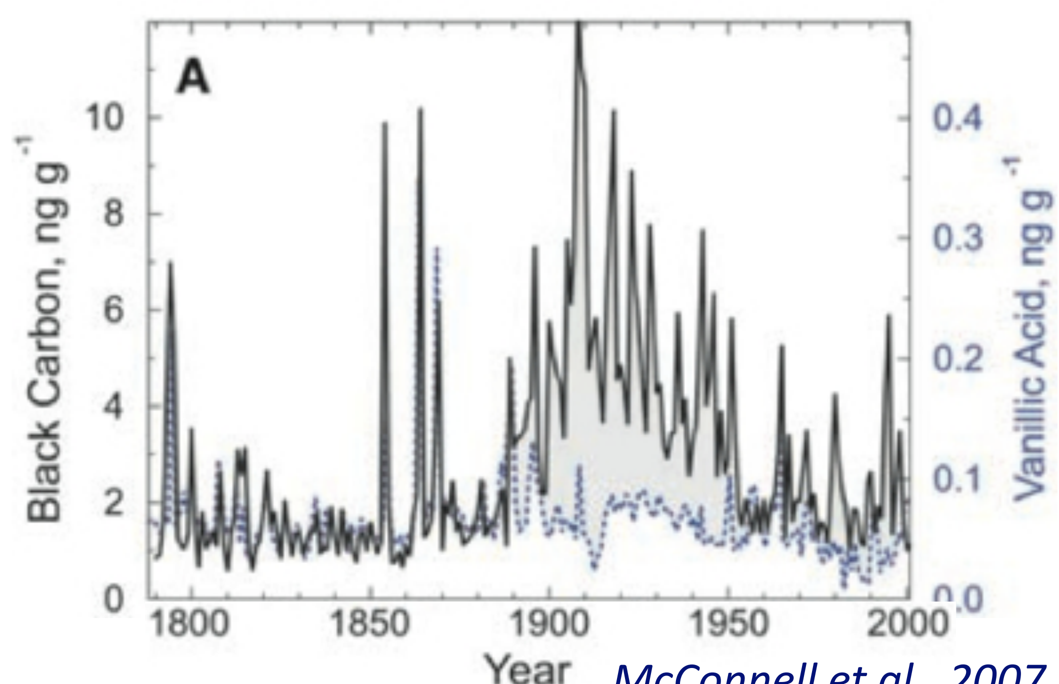


Shindell et al., 2008

- Observations of **BC in snow** and **ice** suggest an important **open burning** influence



Hegg et al., 2009

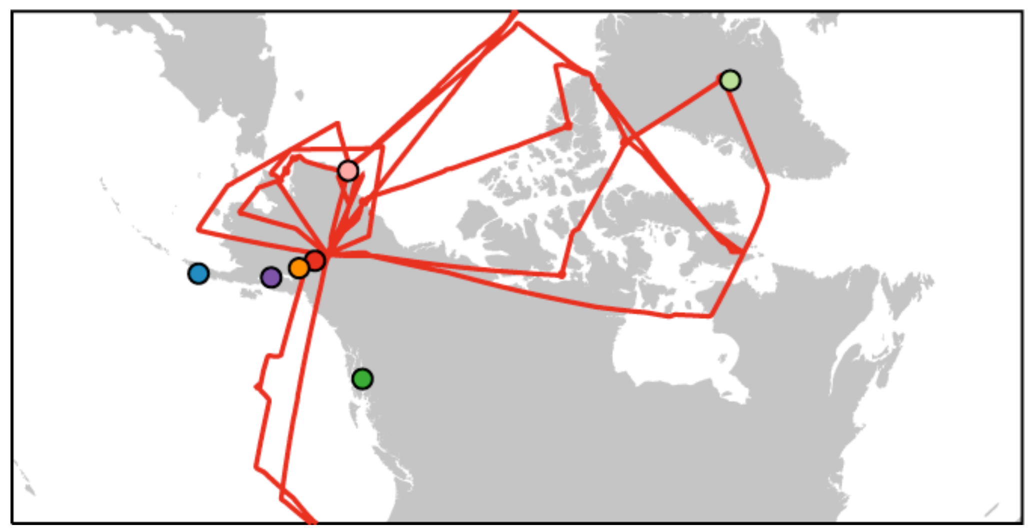


McConnell et al., 2007

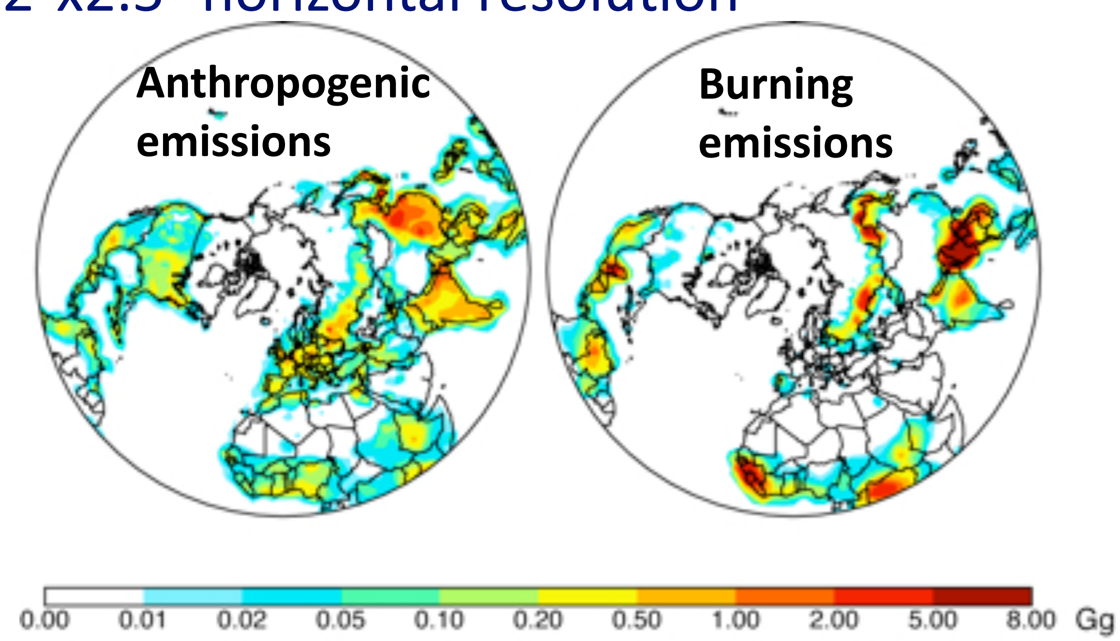
ARCTAS aircraft data provide new constraints on Arctic BC

Approach: Integrated analysis of black carbon aerosol data from:

1. **NASA ARCTAS** aircraft campaign during April 2008, based in Fairbanks, AK
2. **Long-term monitoring sites** at Barrow, Summit, and the IMPROVE network in Alaska



3. **GEOS-Chem** – Chemical Transport Model (CTM) aerosol simulation driven by GEOS-5 meteorology at 2°x2.5° horizontal resolution



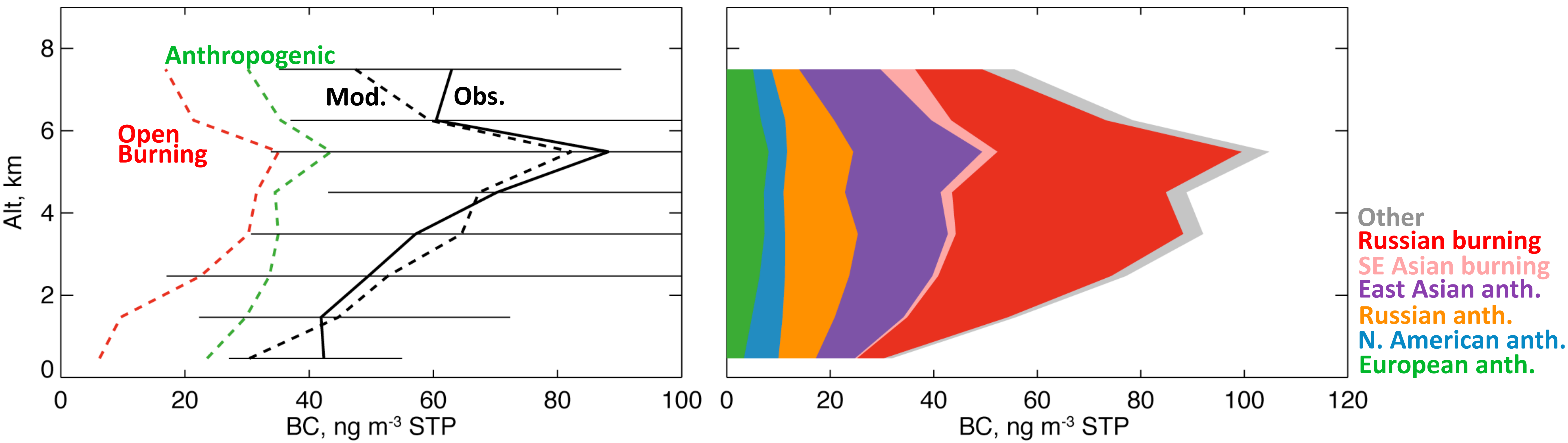
BC emissions

- Anthropogenic (fossil fuel + biofuel): Bond et al. (2007)
  Russian emissions increased by factor of 6 to match data
- Open burning: FLAMBE with scaling from Fisher et al. (2010)
- Total 2008 emissions: 16 Tg, 69% from open biomass burning

Scavenging includes cloud condensation nuclei (CCN) and ice nuclei (IN) + below-cloud rain and snow precipitation

Transport to Arctic previously assessed using carbon monoxide

Anthropogenic and open burning sources contributed to Arctic BC during ARCTAS

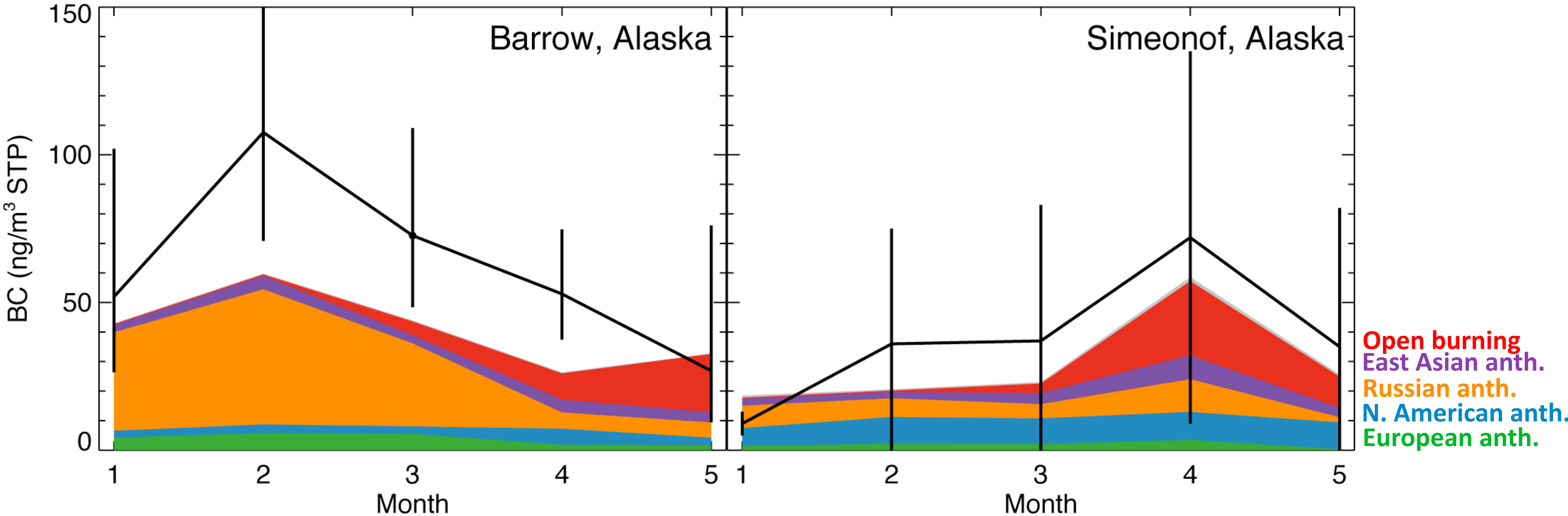


Contributions from **anthropogenic** and **open burning** sources were comparable during ARCTAS (April 2008)

Open burning influence peaks in mid-troposphere

Anthropogenic sources dominate in the lower troposphere

Surface data show seasonal evolution of BC source influences



Anthropogenic sources dominate the winter BC burden at Alaskan surface sites

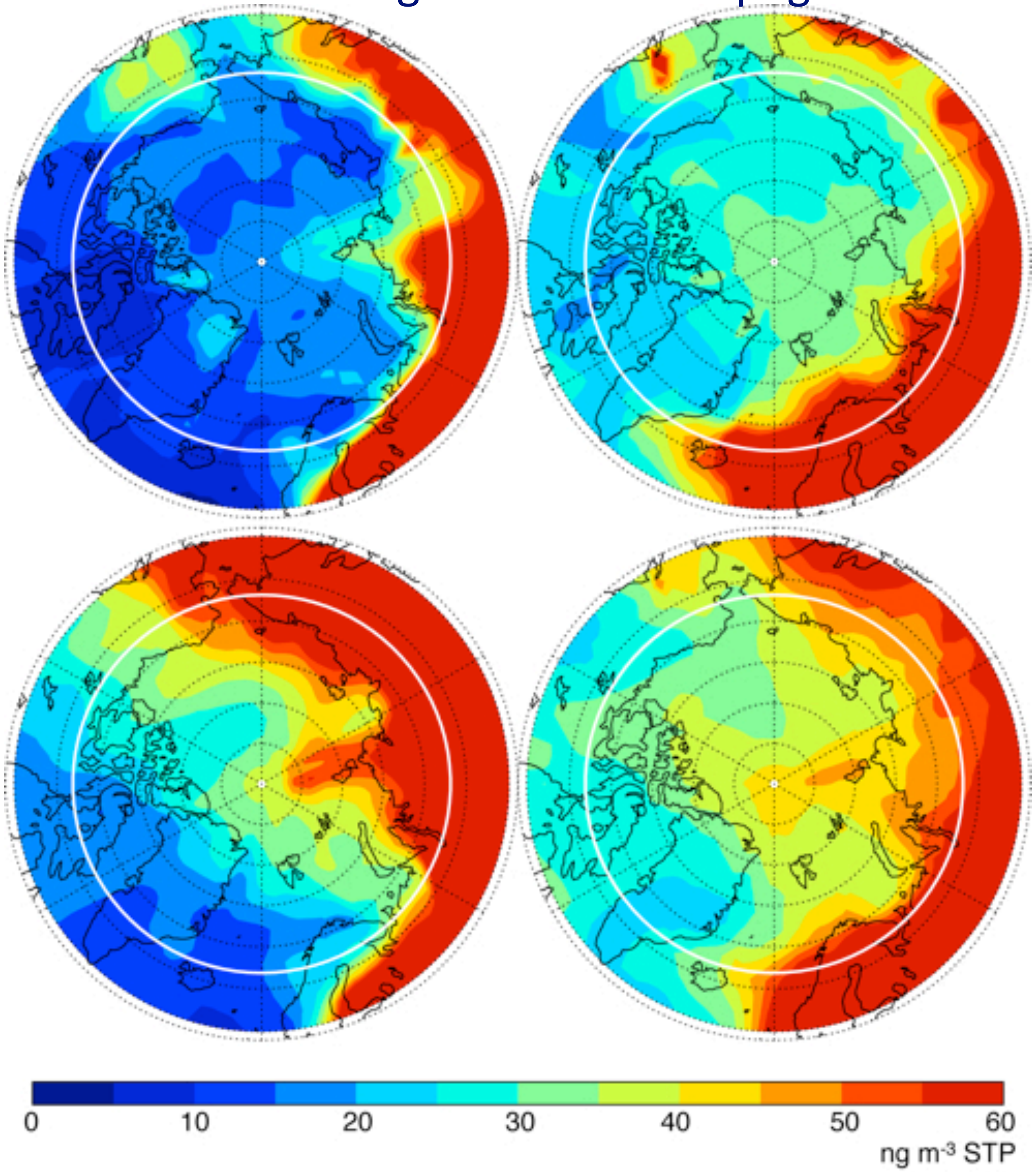
Open burning only becomes dominant in spring; larger influence over Alaska than ARCTAS flight domain

GEOS-Chem provides Arctic-wide picture for April 2008

Biomass Burning BC | Anthropogenic BC

Lowest 1 km

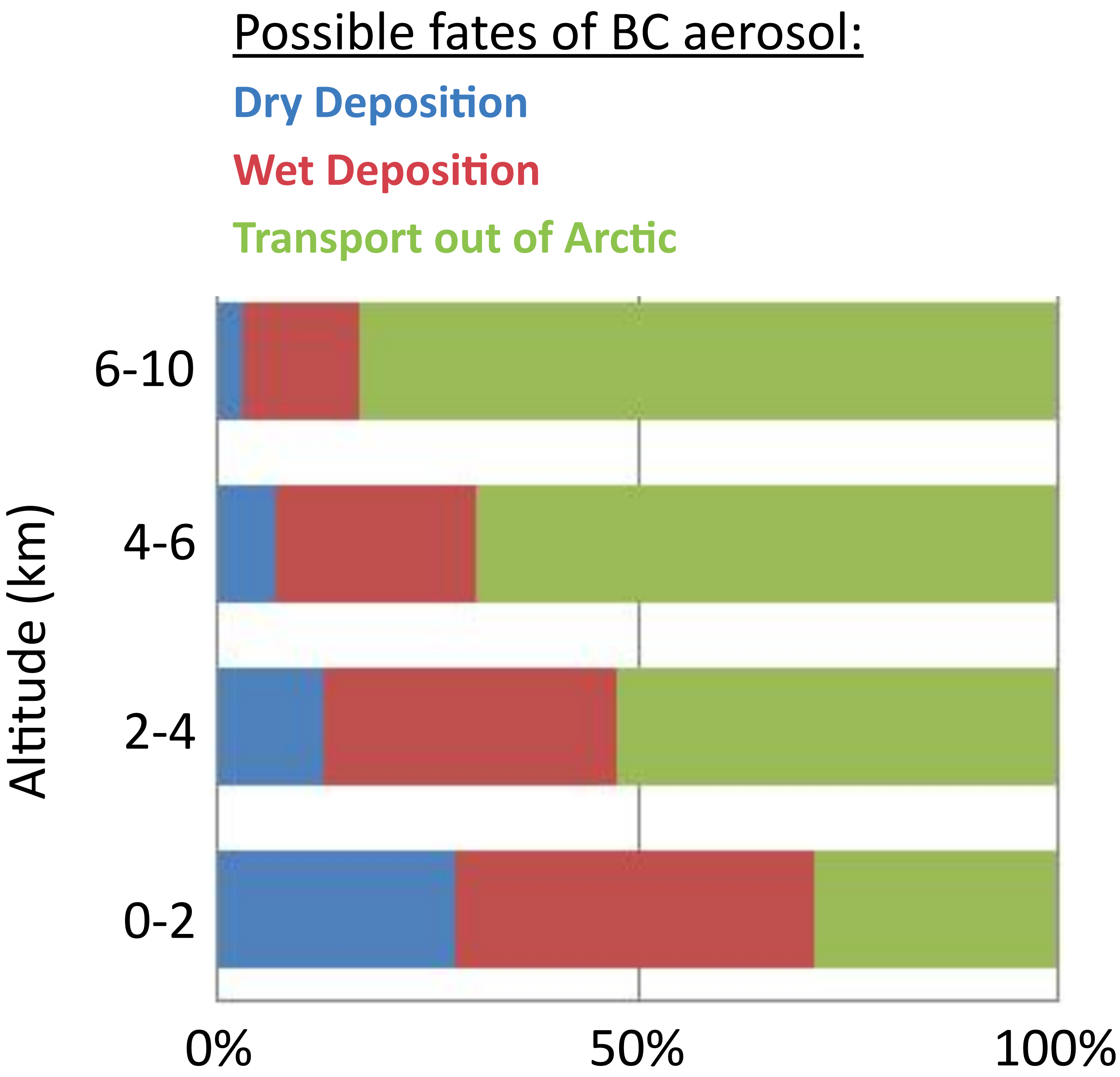
Tropospheric Column



Surface-level BC is dominated by **anthropogenic** sources, except near fire source

Throughout the tropospheric **column**, there is a major contribution from **open burning** (51% of total burden), especially in the Eurasian & Alaskan Arctic

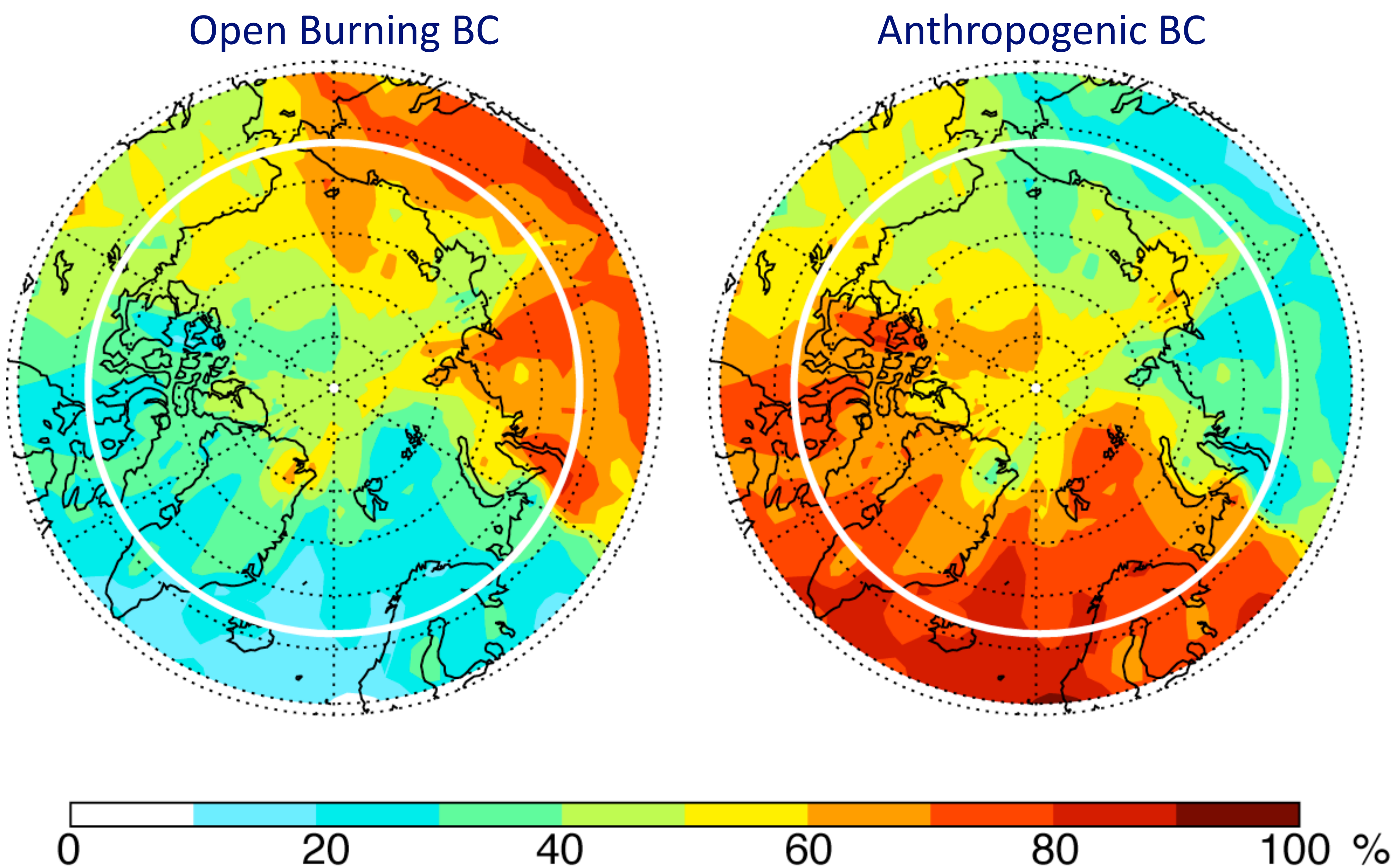
Dominant fate of low-altitude BC is deposition in the Arctic



- Much of the free tropospheric BC is transported out of the Arctic
- BC lifetime of 1 week in the Arctic near the surface
- The majority of low-altitude BC is lost to deposition to the Arctic surface

Sources contributing most to near surface aerosol also contribute to BC deposition in the Arctic

Deposited BC in Arctic spring comes from both anthropogenic and open burning sources

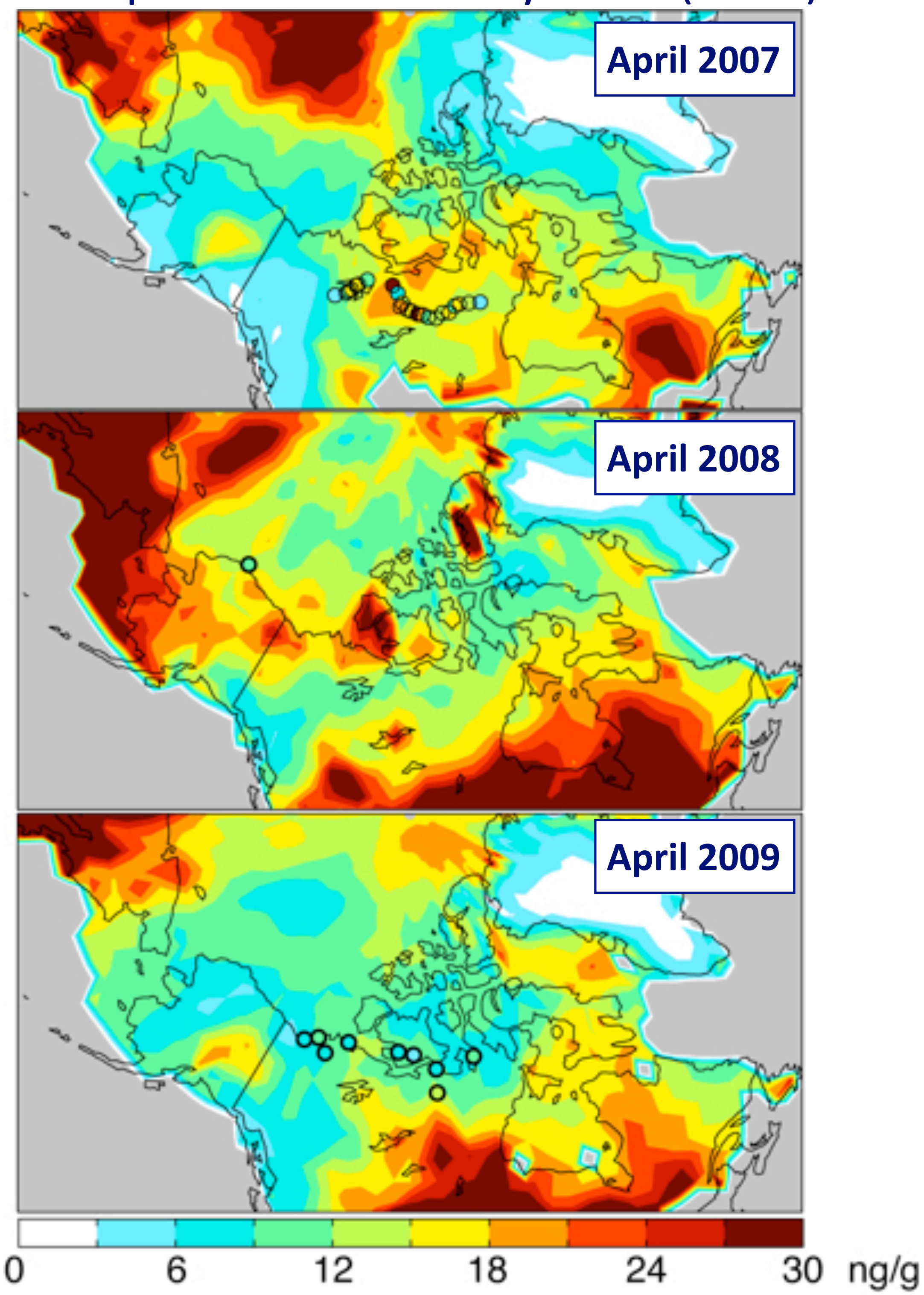


Total BC deposition flux to the Arctic in April 2008: **13.9 Gg** (**49%** from open burning)

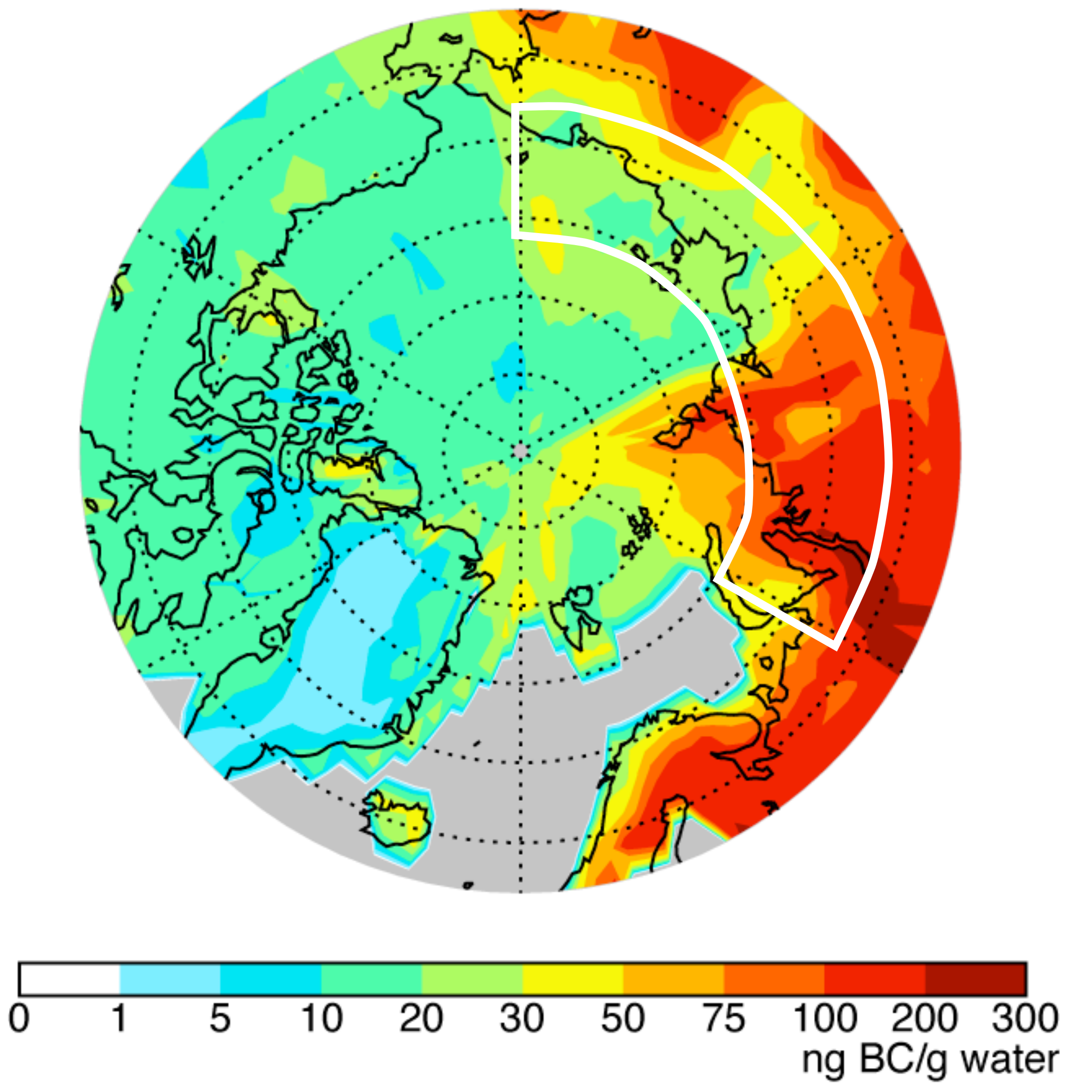
Open burning influence peaks in Eurasian Arctic

Biomass burning enhances spring BC content in snow

Comparison to Doherty et al. (2010)



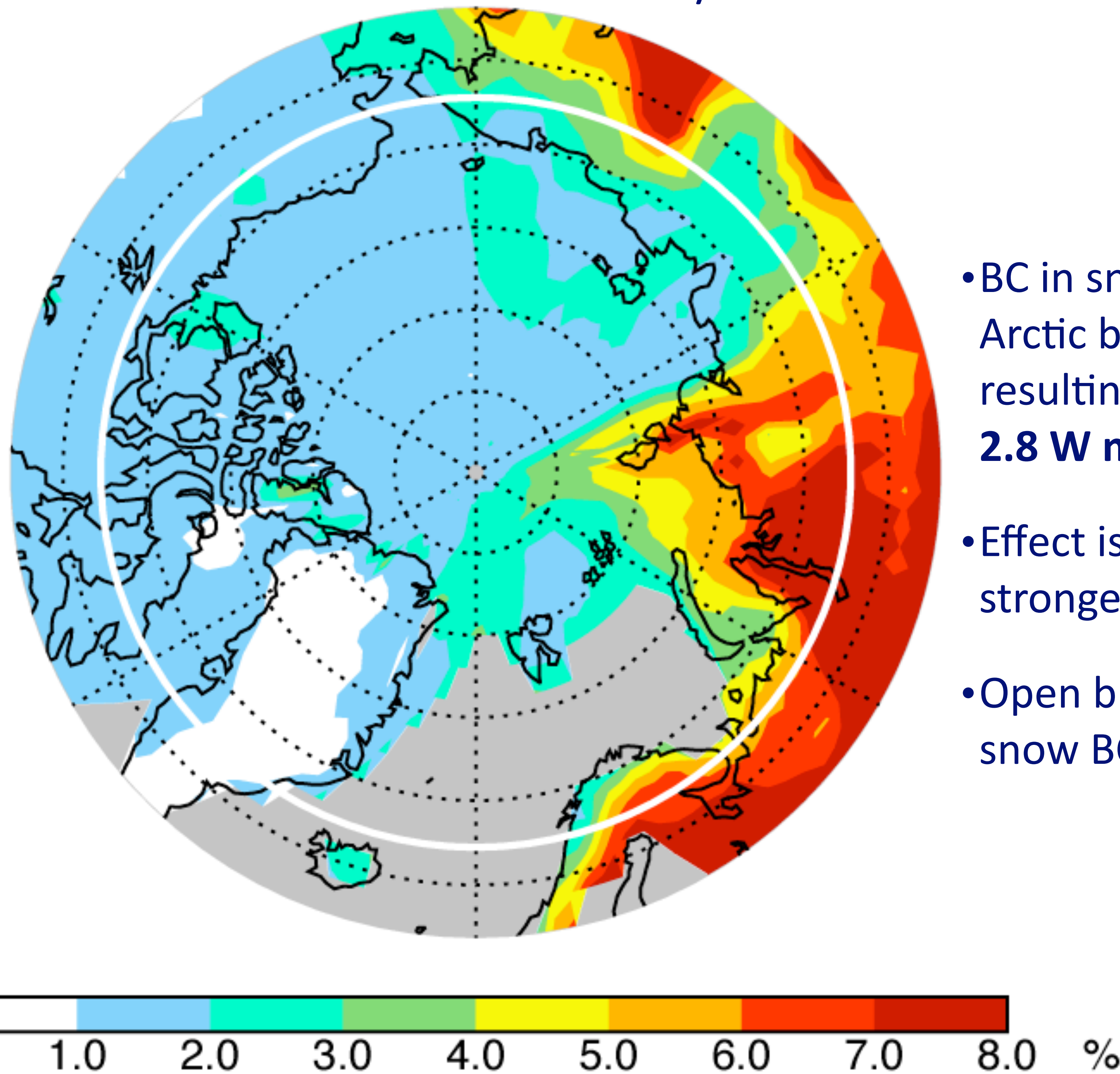
GEOS-Chem simulated snow BC, April 2008



- Simulated snow BC agrees with data from Doherty et al. (2010) over North America (r = 0.70)
- Enhanced snow BC in Russian Arctic in April 2008: mean of 26 ng g^{-1} (mean of 81 ng g^{-1} in May 2008)

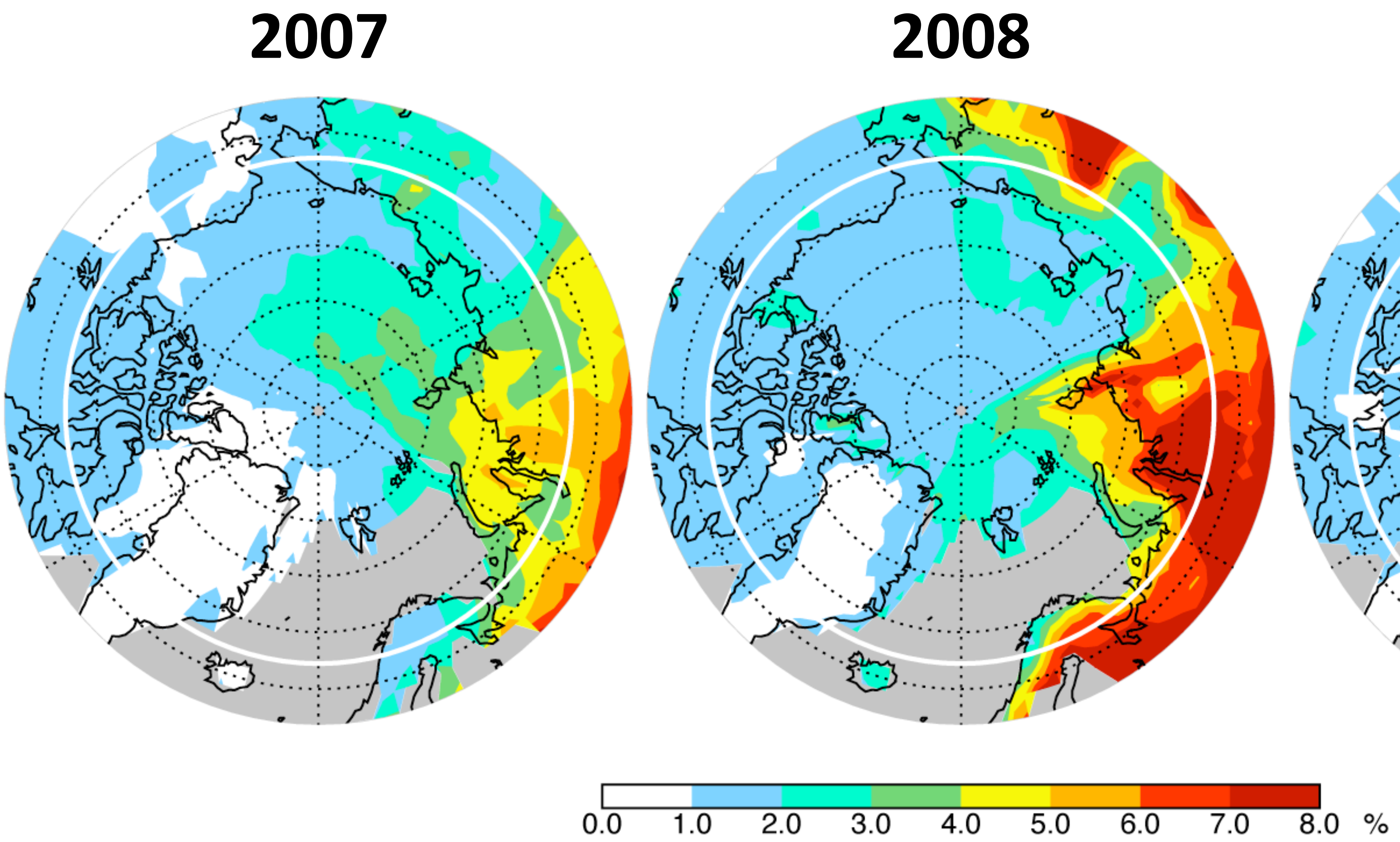
Enhanced snow BC has implications for Arctic surface albedo

BC-induced decrease in snow/ice albedo



- BC in snow decreases albedo over the Arctic by on average **2.0%** in April 2008, resulting in a net Arctic radiative forcing of **2.8 W m^{-2}**
- Effect is weakest over Greenland (<1%), strongest over the Eurasian Arctic (5-10%)
- Open burning responsible for ~45% of snow BC in April 2008

Albedo effect over Eurasian Arctic is large, even in more “normal” burning years



In 2008, anthropogenic and open burning contributions to snow BC were comparable

In 2007 and 2009, anthropogenic BC was clearly dominant and efficiently transported to the Arctic, leading to albedo decreases even without major fire influence

Conclusions

1. Open burning was responsible for roughly 50% of tropospheric Arctic BC in April 2008. Despite the anomalous fire activity in 2008, the anthropogenic contribution was important throughout the tropospheric column and dominant near the surface.

2. The dominant fate for low-altitude Arctic BC is deposition within the Arctic.

3. The enhanced Arctic BC deposition from open burning peaks over the Eurasian Arctic.

4. Overall, BC deposited to Arctic snow/ice decreases albedo by ~2%, with major impacts over the Eurasian Arctic.

5. The net Arctic radiative forcing due to BC in snow in April 2008 was 2.8 W m^{-2}.

Acknowledgments:
NASA Tropospheric Chemistry Program, ARCTAS Science Team